# KIC-InnoEnergy PROJECT NEPTUNE

## Development of a floating lidar buoy for wind, wave and current measurements

Authors: Frieder Schuon(1), Daniel González (2), Francesc Rocadenbosch(3), Oliver Bischoff (4), Ramón Jané(5)

(1) IREC, Catalonia Institute for Energy Research Jardins de les Dones de Negre, 1, 2a pl. E-08930 Sant Adrià de Besòs, Barcelona (Spain) fschuon@irec.cat

(2) Universitat Politècnica de Catalunya (UPC), Laboratori d'Enginyeria Marítima (LIM/UPC), c/ Jordi Girona 1-3, Campus Nord-UPC, Edif. D-1, E-08034 Barcelona, Spain. daniel.gonzalez-marco@upc.edu

(3) Universitat Politècnica de Catalunya (UPC), Remote Sensing Lab. (RSLAB/UPC), c/ Jordi Girona 1-3, Campus Nord-UPC, Edif. D-4, E-08034 Barcelona, Spain. roca@tsc.upc.edu

(4) SWE, Stiftungslehrstuhl Windenergie am Institut für Flugzeugbau Universität Stuttgart Allmandring 5B, D-70550 Stuttgart. oliver.bischoff@ifb.uni-stuttgart.de

(5) Gas Natural SDG, S.A. Plaça del Gas, 1 E-08003 Barcelona, rjane@gasnatural.com

**Summary:**

The KIC-InnoEnergy project "NEPTUNE" develops a floating Lidar buoy and a hindcast- and forecast model for wind- wave- and current measurements of offshore wind farms. In this paper just the lidar buoy is presented and discussed: Main challenges, the design ideas and the steps to develop, test and prototype this product, which – according to the KIC-InnoEnergy project idea – should be commercialized after the project end, foreseen for the end of 2014. KIC-InnoEnergy is funded from the European Institute of Technology, EIT.

### 1. Introduction:

Large offshore wind farm investments need reliable wind resources and site condition measurements.

In shallow water a met-mast can be installed with reasonable costs or in case of open sea the wind resource is predictable from existing data and numerical calculations. In case of deepwater, the costs would exceed reasonable limits for a floating or a very tall bottom fixed metmast. In the special case of the Mediterranean Sea, but also in other seas, where we find the combination of deepwater and difficult predictable wind and wave systems, a precise, but economical wind measure system is indispensable.

For IREC's test wind farm for floating wind turbines "Zèfir", planned in the Mediterranean Sea close to Tarragona (100km south of Barcelona), an international consortium, lead by IREC, decided to develop within the KIC-InnoEnergy project "NEPTUNE", a Lidar metocean buoy, which will be capable to measure wind data up to more than 200m, waves and sea currents.

### 2. Challenges for such a Lidar buoy

#### 2.1 General idea:

This buoy has to measure accurately all important site specific data for an offshore wind farm. Special evaluation software will be also provided to analyse typical wind energy information in the smartest and best way from buoy data. The data should not only be used just for measurements, but also to adjust and to validate numerical wind and oceanographic simulation models. This is, later in wind farm operation, of enormous importance to reduce costs and risks of O&M. The Lidar for the prototype buoy is the continuous wave Lidar ZepHIR Z300. The development considers the Lidar as a black box to avoid a strong dependency to only one Lidar manufacturer in a future serial production.

#### 2.2 Buoy size and Lidar motion compensation

Wave measurements from buoy acceleration need a small size; a Lidar requires the opposite, a more stable platform. The buoy design is therefore a trade-off between both, but with priority to the Lidar needs, because wind data need a really high precision to be useful for wind energy applications. In order to reduce the Lidar motion, a mechanical motion compensation frame is under development. The project makes numerical simulations to optimize buoy size and Lidar motion compensation. Tests in the development and validation phase will focus extremely on the high quality lidar measurements. In addition, the team works on software to correct the measured data also by post processing software.

### 2.3 Sensors and communication

Wave data - heights and direction - come from buoy acceleration measurements. The Lidar motion will also be measured to mark data which have low certainty due to extreme motion and the aforementioned mentioned post process correction needs this input, too.
An acoustic Doppler current profiler (ADCP) quantifies water current data of different depth levels according to the site.

All meteorological data, such as temperature (air and water surface), air pressure, wind speed and direction on buoy top height, humidity, etc. are stored in a central data logger, which collects all data from all sensors and sends it in data packages to land. According to the communication system the data packages, the size and the sending frequency can be adjusted.

Depending on the site, data will be transmitted via WIFI, radio modem, GPRS or satellite.

As a naval tool, the buoy must have navigation lights and the required warning signals or systems. Also very important is an emergency satellite positioning system which is activated in case that the buoy leaves a predefined range of coordinates. It sends then alerts and current positions to land.

### 2.4 Energy autonomy

Indispensable is that such a buoy must be completely autonomous in terms of energy. For all these sensors, communication and navigation systems, an average power of 120W will be provided by solar panels on the buoy surface and up to three small wind turbines. In case of no wind and no sunshine, a battery pack has to store at least 60h of energy. A Diesel generator is not foreseen, it would make the buoy too complex and heavy. Also the fact that a bigger amount of oil has to be on board makes it much more complicated in legal and O&M requirements. A wind vane in one side of the cover keeps the buoy generally oriented in good working direction and reduces problems with mooring systems.

The overall buoy mass is estimated with 3.9tn and the width of about 4m.

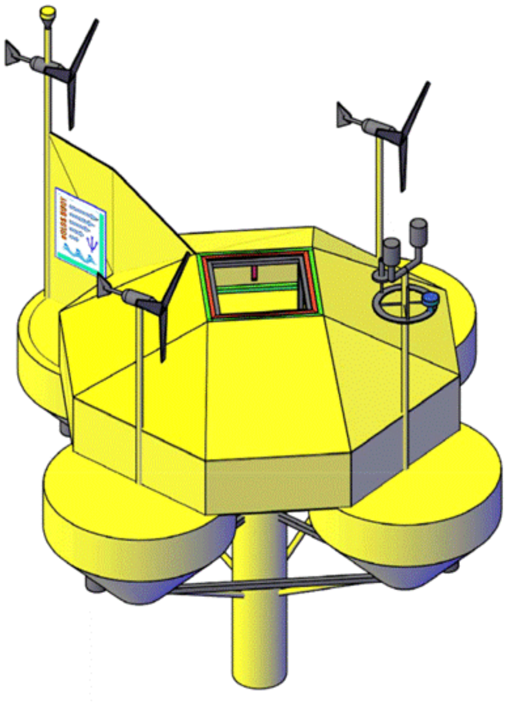

**Fig. 1:** Sketch of the Lidar buoy named “EOLOS”

## 3. Steps of development, tests and prototyping

Extremely important is that the development and validation of the Lidar system goes step by step and it has to guarantees a perfect working in the future buoy.

### 3.1 Land tests

In the first step we make with two identical fixed Lidars a side-by-side measure campaign to show the optimal expected correlation between two Lidars. Different distances between the instruments shall also demonstrate the influence of this parameter which later in sea tests will vary according to the local situations. 1-second and 10-minute data are the treated signal outputs; even the buoy will generally use later analysis from 10min data.
After these base tests, one Lidar will be installed on a motion platform, which simulates the buoy motion. In a first stage no motion compensation is applied on the Lidar to have the information, which is the measurement accuracy without any compensation and correction.

Later the moving Lidar will be mounted in the mechanical motion compensation frame, of the prototype buoy. Also software to correct the data by post processing will be tested now. In base of these measurements both, the mechanical frame, but also the software can be optimized.

**3.2 Sea validation of Lidar measurements**

After having tuned and tested the motion compensation systems, all has to be validated on sea. On a 250m pier close to the IREC facilities, we will make again side-by-side tests: One fixed Lidar on the pier platform and 20-50m from there the provisional buoy with the Lidar on the motion compensation frame.


**Fig.2:** Test site for first sea tests: *Pont de Petroli* close to Barcelona, with a sea depth of 11m

**3.3 Factory tests**

Next step is to assembly the complete buoy with all sensors, energy generators and communication systems. Of course intensive factory tests have to follow before the buoy can be deployed in a provisional position to prove the resistance of all components against the aggressive sea environment.

**3.4 Sea prototyping**

To test really the buoy itself, it is foreseen to make a 1-year sea campaign to measure the site conditions of the Zèfir Test Station Phase 2 for floating wind turbines close to Tarragona in the Mediterranean Sea.
This long campaign should really show all weaknesses and should give time for improvements. The measured data not only will be used analyzing the site conditions of the test farm for floating wind turbines, but also to validate the wind and sea state forecast tool developed in another work package of the NEPTUNE project.

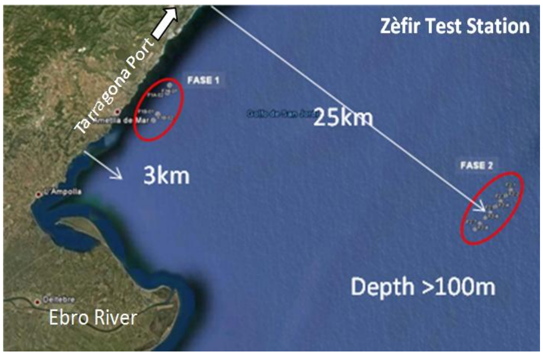


**Fig. 3:** Zèfir Test Station Phase 2 will be the position for the 1 year measure and prototyping campaign of the buoy. Mediterranean Sea, 100km south of Barcelona

**3.5 Buoy assessment**

While or after this campaign it is necessary to carry out a 3rd party assessment of the measure system to make sure that the market will accept the buoy as a good and cost effective tool for such kind of measurements. It is foreseen that the assessment could be done against a metmast to be installed in Zèfir Phase 1 about 3km from the coastline. Nevertheless due to a certain mismatch of the schedule of NEPTUNE and the Zèfir Metmast the consortium is also looking for other options.

**4. Outlook**

In parallel to the buoy development the NEPTUNE team is also working on special software to post process and evaluate buoy data specifically for wind energy needs.

Also ongoing is a market and business study – one of the requirements in a KIC-InnoEnergy project. From these studies the consortium expects to know better the market needs in order to optimize the product(s) and the business based on it.

The project end is schedule end of 2014 and the consortium expects to start up the commercialized buoy from 2015 on. These buoys of course must be adapted on the needs of the market and it has to be suitable for all sea conditions where the market is, not only the Mediterranean Sea. The serial buoy should cover shallow and deepwater sea conditions to open the widest market and to be useful in the best way for offshore wind energy.